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INJURED AND DEAD FISH IN THE VICINITY OF BONNEVILLE DAM

SPECIAL SCIENTIFIC REPORT: FISHERIES No. 29

UNITED STATES DEPARTMENT OF THE INTERIOR
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United States Department of the Interior
Oscar L. Chapman, Secretary
Fish and Wildlife Service
Albert M. Day, Director

Special Scientific Report - Fisheries
No. 29

INJURED AND DEAD FISH

IN THE VICINITY OF BONNEVILLE DAM

By

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INTRODUCTION

The following report is the result of a study made jointly by the Fish and Wildlife Service and the War Department, Corps of Engineers to determine (1) the mortality of adult fish above and below Bonneville Dam, and (2) the extent of visible injuries to adult fall chinook salmon at Big White Salmon Hatchery above the dam and at Bonneville Hatchery just below the dam.

Bonneville Dam and related facilities were constructed by the Corps of Engineers, for improvement of navigation and the development of hydroelectric power. It was built across the Columbia River about 140 miles upstream from its mouth and about 40 miles east of the City of Portland.

On the following pages will be found the summary and conclusions of the investigators on the studies conducted. A description of the problem, the methods of investigation, and the data collected during the study are presented in Sections I and II. Section III is an appendix showing tables of pertinent data and maps illustrating the areas and orienting the studies in the preceding sections.

The investigation was under the general supervision of J. T. Barnaby, In Charge, North Pacific Fishery Investigations, Fish and Wildlife Service. Harry A. Hanson of the Service directed the work in the field. He was assisted by Paul D. Zimmer, Russell L. Bagwell, Eugene M. Maltzeff and Curtis P. Jensen of the Service, and Ivan J. Donaldson of the Corps of Engineers. Other members of the Corps of Engineers and local residents contributed information and services which measurably facilitated the progress of the investigation. Personnel of the Columbia River Packers Association stationed at Ellsworth cannery graciously made available their dock and moorage facilities for operations at that point.

With the building of Bonneville Dam several problems arose concerning the runs of anadromous fishes in the Columbia River and its tributaries. The first problem was to provide safe passage for adult fish on their journey upstream to spawn. This was accomplished by building an elaborate collection system, together with fish ladders and fish locks which enable the fish to swim up around the dam or to be "locked" through the locks. Secondly, and of equal importance, was the installation of fish screens and bypass channels to facilitate the downstream movement of the seaward migrants.

Since the earliest mention of plans for a dam at Bonneville, there has been considerable speculation about its effect on salmon, steelhead, and other fish. Soon after completion of the dam and its component parts, many commercial fishermen and anglers reported seeing dead salmon and

other fishes floating downstream below the dam at various times of the year. The Corps of Engineers accordingly instructed its biologists to make periodic trips downstream in a boat to learn the extent of mortality, and if possible, to determine if the fishes died as a result of injuries received at Bonneville Dam. These studies have been carried on for the past eight years (Appendix, Table 3). Data obtained during the fall migration period in September 1946 by the U. S. Fish and Wildlife Service in cooperation with the Corps of Engineers are included in the text.

SECTION I

INJURED FISH STUDIES

Injuries Observed at Bonneville Dam. For several years, it has been the practice for the fish counters at Bonneville Dam to keep a record of the number of injured fish observed. Prior to 1941 they had recorded merely that there was an apparent injury on the fish, and then only those injuries deemed "Serious" were recorded. In May 1943, during the height of the spring run of salmon, a more detailed record was kept, showing not only the number of injuries but also the type and location of each injury.

Injuries, 1943. In a sample of 37,805 chinook salmon passing up the ladders during May of 1943, 339 showed injuries. Of this number, 165 or about 49 percent were injuries to the dorsal fin, and the remaining 174 were injuries to other parts of the body of the fish.

Net Injuries, Chinook Salmon, 1946. In the summer of 1946, a series of sample counts was made at counting stations in the fish ladders at Bonneville Dam to determine the frequency of net marks and other injuries. Injuries other than those obviously caused by nets were wounds and abrasions on various parts of the body of the fish. In some cases, there were deep gouges on the flesh along sides and peduncle area. In others, large torn patches of skin were hanging loose, leaving the muscle tissue exposed; and in still others, fungus patches had begun to form on previous cuts or abrasions on the snout and tail. The numbers of net and other injuries during June, July, and August 1946 are shown in Table 1.

Injuries Observed Above and Below Bonneville Dam. In order to determine whether there were more injured fish above Bonneville Dam than below and the types of injuries present at each locality, observers were stationed at Big White Salmon and at Bonneville Hatcheries during the height of spawning activities. Big White Salmon Hatchery is on the Washington Shore approximately 30 miles above the dam, and Bonneville Hatchery is approximately one mile below the dam on the Oregon shore.

At each hatchery the observers daily recorded the following data for chinook salmon: (a) total number of fish examined, (b) dorsal and ventral fin cuts or abrasions, (c) completely encircling abrasions, and (d) other injuries.

Table 1. Number of blueback and chinook salmon and steelhead trout counted, number of fish in various samples taken, and number of injured fish observed in each sample at Bonneville Dam during June, July, and August 1946.

Date	A* Total count	A* Number in sample	B Number w/ encircling abrasions	B/A Percent	C* Number in sample	D Number w/ other injuries	D/C Percent
1946			STEELHEAD TROUT				
June	3,265	1,466	72	4.9	--	--	--
July	20,559	11,762	378	3.2	10,097	197	1.9
August	58,356	46,747	3,157	6.7	48,687	594	1.2
			BLUEBACK SALMON				
June	7,805	3,290	71	2.2	--	--	--
July	64,704	46,605	1,902	4.0	41,411	475	1.1
August	1,746	797	54	6.8	836	38	4.6
			CHINOOK SALMON				
June	30,051	24,099	1,023	4.2	16,604	973	5.9
July	20,960	13,042	718	5.5	17,808	1,545	8.7
August	45,421	28,403	2,463	8.7	27,028	978	3.6

*These numbers represent the sum of the samples counted each day.

The study at the two hatcheries was concerned with fall-run fish which did live until spawning time in the hatcheries; therefore, injuries such as cut or mutilated dorsals and ventrals and encircling abrasions did not cause the premature death of these fish. Such injuries to spring-run fish that must remain several months longer in waters of the upper tributaries before reaching sexual maturity might cause a high mortality because of fungus or other infections.

Big White Salmon Hatchery. At this hatchery, salmon ascend a small fish ladder, enter a long concrete pool, and remain several days to complete development of their eggs and sperm. From here the males and females are sorted and placed in separate holding areas in an adjacent pool. There are no nets used in these operations, and consequently observers believed it impossible for the fish to get dorsal or ventral fin injuries or encircling abrasions in either the fish ladder or the hatchery pools. The number of fish examined at the Big White Salmon Hatchery and the number of injured fish observed are presented in Table 2.

Table 2. Number of chinook salmon examined at the Big White Salmon Hatchery (approximately 30 miles above Bonneville Dam) and number of injured fish observed* during the period September 24-October 4, 1946.

Date	Total examined	Dorsal fin abrasions		Ventral fin abrasions		Encircling abrasions	
	No.	No.	Percent	No.	Percent	No.	Percent
9/24/46	547	159	29.1	120	21.9	35	6.4
9/26/46	1,207	264	21.8	200	16.6	50	4.1
10/4/46	409	76	18.6	74	18.1	17	4.2
Totals	2,163	499	23.0	394	18.2	102	4.7

* In addition to the injuries noted in the table, 37 fish or 1.7 percent had open body wounds.

Of the 499 fish with dorsal-fin injuries, 78.9 percent had the accompanying ventral-fin injuries. All of the fish with encircling abrasions had both dorsal and ventral cuts. It is apparent in Figures 1 and 2 that these injuries were caused by nets.

Out of the total sample of 2,163 fish examined, 37 or 1.7 percent had open body wounds. Two fish had open cuts in the peduncle area. The other 35 fish had cuts just back of the head or crescent-shaped wounds on the underside between the pectoral fins. No explanation is available of the source of these injuries.

Bonneville Hatchery. Tanner Creek, which flows through the hatchery holding ponds, empties into the Columbia River about a mile below Bonneville Dam. As the fish enter Tanner Creek, most of them proceed upstream through the raceway and directly into the hatchery holding ponds. A portion of the later arrivals, however, remain in the raceway.

The fish that have entered the holding ponds are collected for sorting by the use of a 3 1/2 inch stretched-mesh seine. Males are separated from females and placed in separate holding areas. At the time of spawning operations, these fish are again collected by seining.

When the time arrives to collect spawn from the fish that have remained in the raceway, the flow of water is decreased to permit seining. Again the 3 1/2 inch seine is used for collecting the fish. It was considered impossible for the fish to get dorsal, ventral, and encircling abrasions in the net used because of the small size of the mesh.

On September 20, the observer at Bonneville Hatchery recorded only dorsal-fin injuries, and it was found that these occurred on 28.5 percent of the 56 fish examined on that day.

Figure 1.-- Chinook Salmon with dorsal and ventral fin injuries observed at Big White Salmon Hatchery.

Figure 2.--Chinook Salmon with dorsal and ventral fin injuries plus the completely encircling abrasions observed at Big White Salmon Hatchery.

Table 3. Number of chinook salmon examined at the Bonneville Hatchery (approximately one mile below Bonneville Dam) and number of injured fish observed* during the period September 25-30, 1946.

Date	Total examined	Dorsal fin abrasions		Ventral fin abrasions		Encircling abrasions	
	No.	No.	Percent	No.	Percent	No.	Percent
9/25/46	162	46	28.4	38	23.4	5	3.1
9/25/46	65	18	27.7	12	18.5	7	10.7
9/30/46	283	70	24.7	61	21.5	10	3.5
Totals	510	134	26.9	111	19.6	22	3.9

* In addition to the injuries noted in the table, 12 fish or 2.4 percent had open body wounds.

It may be pointed out that of the total of 510 fish examined on September 25 and September 30, 26.9 percent had dorsal-fin injuries (Figure 3), 19.6 percent had ventral-fin injuries (Figure 4), and 3.9 percent had well-defined encircling abrasions (Figure 4).

Of the 134 fish with dorsal-fin abrasions, 82.8 percent had the accompanying ventral-fin injury. All of the fish with encircling abrations had both dorsal-and ventral-fin injuries.

Other injuries to fish observed at Bonneville Hatchery in the sample of 510 examined on September 25 and September 30 showed 2.4 percent had open wounds about the body. Several of these fish had crescent-shaped cuts on the underside of the body between the pectoral fins very similar to many of the injuries observed at Big White Salmon Hatchery. No explanation is available as to the cause of such injuries.

In September 1945, Robert R. Rucker of the Service made observations of injured fish above and below Bonneville Dam. The following quotation is taken from his monthly report of activities. Complete text of his observations is given in the Appendix.

> "On September 15, the gill-net caught chinook salmon from immediately below and above Bonneville Dam were examined. It was desired to determine whether or not the fish taken above the dam showed a greater percent with injuries on the dorsal fins. Of 170 chinook salmon taken below the Dam, 19% showed an injury on the dorsal fin: of 100 chinook salmon taken above the Dam, 19% showed an injury on the dorsal fin. These data indicate that the dorsal-fin injury is probably not incurred by the fish in the fishways at Bonneville Dam."

Observations of Fish Passing Through Submerged Openings in Bonneville Fish Ladder. Preliminary to the study of salmon mortality of the Columbia River in the vicinity of Bonneville Dam, a conference was held between personnel of the Fish and Wildlife Service and representatives of the Corps of Engineers at Bonneville. It was decided that it would be desirable

Figure 3.--Chinook Salmon with dorsal fin injuries observed at Bonneville Hatchery.

Figure 4.--Chinook Salmon with ventral fin injuries and completely encircling abrasions observed at Bonneville Hatchery.

to observe the action of salmon in the Bonneville fish ladders as the fish passed through the submerged orifices in the weirs. Such observations, it was believed, would determine whether or not the injuries observed at the counting stations and at the hatcheries could have been sustained in the ladders. Consequently, the Corps of Engineers built a submersible operation chamber for the purpose (Figure 5).

The chamber was made of an 8-foot section of galvanized-iron culvert pipe, three feet in diameter. The lower end was welded to a steel plate, 5/8 inch thick and seven feet square. The pipe and its base were strengthened by having four steel-rod stays of 7/8 inch diameter fastened to the upper ring of the pipe and the plate base to which it was welded. A 4 inch vertical flange was welded to each of the four sides of the base plate, forming an open box to hold the iron weights used in submerging the lower part of the chamber. About 3,200 pounds of cast-iron weights were necessary to overcome buoyancy. Two watertight glass observation ports were built into the walls of the chamber. One of the ports was 12 inches and the other 24 inches from the floor. The glass ports were made of clear plate glass, 3/16 of an inch thick and about 12 inches square. The device was provided with a cover to exclude light from above.

On September 5, 1946, the observation chamber was lowered into the fish ladder in the first pool below the Bradford Island counting station. From the chamber, large numbers of chinook salmon and steelhead trout were observed passing through the submerged orifice in the lower weir of the pool. The velocity of the water passing through the opening was about five feet per second.

The following statement was taken from office memorandum of October 8, 1946, subject "Fishway Observation," by Mr. F. L. Abbott, Superintendent of Fishways at Bonneville Dam. (Copy of memorandum and letter of transmittal included in Appendix I) "Fish do at times, rub the top and sides of orifices, but several different observers agree that they saw no fish passing through which, in their opinion, rubbed hard enough to be injured. From my own personal observation, I am not prepared to say definitely that fish are not in some instances injured."

Two 200 foot reels of 16 mm., motion picture film showing the actions of the fish while passing through the submerged orifice were taken, and these are kept at Bonneville Dam in the office of the U. S. Corps of Engineers.

Figure 5.--Submersible chamber built by U.S. Corps of Engineers to observe fish movement in the Bonneville fish ladder.

SECTION II

ADULT FISH MORTALITY STUDIES - 1946

Float Experiment. As part of the program of studies to determine the extent of mortality of fishes in the Columbia River below Bonneville Dam in 1946, it was considered advisable to learn the direction and influence of wind drift during the peak of the fall run of salmon passing Bonneville. We believe that this information would enable us to determine the speed at which the river carried floating dead fish downstream. To obtain such data, 100 wooden floats were constructed that would be subjected to approximately the same degree of wind, wave, and current action as floating dead fish (Figures 6 and 7).

The body of each float was of wood, 2 inches thick, 4 inches deep, 24 inches long, and painted bright yellow. Holes were bored in the underside of each, and two railroad spikes were inserted, one on each side of the center and 12 inches apart. Two 8-penny spikes were also driven partway into the underside, one on each side of the center and 18 inches apart, to balance the floats and to keep them partially submerged. Each float was fitted with a red and white flag, tied to an 18 inch wire rod mast. Fifty floats had the red half of the flag on top, and the other 50 had the white half on top. The flags, three inches wide and ten inches long, offered very little resistance to the wind.

Since there is always a marked difference in the rate of flow of water between the spillway channel and the powerhouse channel during the low-water period of August and September, it was decided to release 50 floats in each channel. Accordingly, at 1:00 a.m. on August 28, 50 floats with white-top flags were released in the powerhouse channel. At the time of release of the red-top floats in the spillway section, all spillway gates had been closed, resulting in nearly dead water in this channel, and we decided to use only the floats with white-top flags in determining the rate of river flow. Nineteen of the red-top floats went aground on the end of Bradford Island. At 4:00 a.m., spillway gates were opened, and as a result, sufficient current developed in the channel to take the 31 floats released after that time downstream to the confluence of the two channels. Water was flowing through the powerhouse channel at about 32,000 cubic feet per second during the experiment (Appendix, Table 1).

Two observers left the dam in a boat at 5:00 a.m. August 28, to follow the floats downstream. They saw floats distributed along their route for the first seven miles below the dam. The "Sandy" arrived at Cape Horn, 13 miles below Bonneville, at 6:30 a.m., where the observers remained to record the time the floats passed. The first float passed Cape Horn at 9:05 a.m. Table 4 is a record of the day's observations.

Figure 6.--Wooden float used in experiment to determine direction and influence of wind drift below Bonneville Dam.

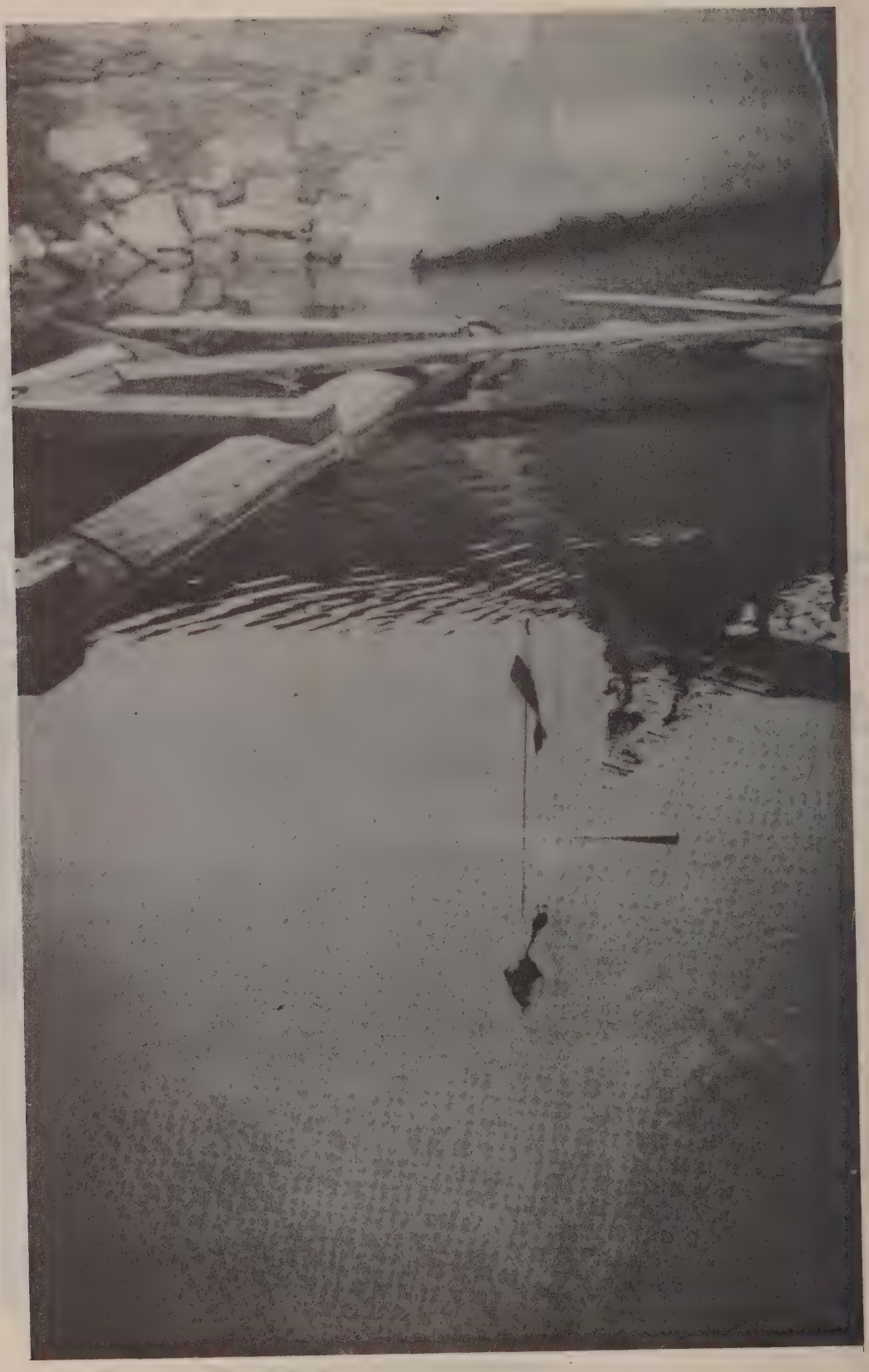


Figure 7.--Position of wooden float in water.

Table 4. Number, hour of appearance, time elapsed, and rate of travel of red-top and white-top floats released at Bonneville Dam 1:00 a.m. August 28, 1946, and observed passing Cape Horn, 13 miles downstream.

Red-top 1/ floats	White-top 2/ floats	Time Observed	Time elapsed (hours)	Rate of travel (miles/hour)
No.	No.			
-	1	9:05 a.m.	8.08	1.61
-	1	9:08 a.m.	8.13	1.60
-	1	9:26 a.m.	8.43	1.54
-	1	9:32 a.m.	8.53	1.52
-	1	9:40 a.m.	8.67	1.50
-	1	9:46 a.m.	8.77	1.48
-	1	9:56 a.m.	8.92	1.45
-	1	10:01 a.m.	9.02	1.44
-	1	10:20 a.m.	9.33	1.40
-	1	10:21 a.m.	9.35	1.39
-	1	10:33 a.m.	9.55	1.36
-	1	10:36 a.m.	9.60	1.35
-	1	10:54 a.m.	9.93	1.30
-	1	11:02 a.m.	10.03	1.29
1	-	12:06 p.m	3/	3/
-	1	1:00 p.m.	12.00	1.08
-	1	1:38 p.m.	12.63	1.03
1	-	2:10 p.m.	3/	3/
2	16	--	--	--

1/ Fifty red-top floats were released in spillway channel. Of these, 37 were beached on the Washington shore and 11 were unaccounted for.
2/ Fifty white-top floats were released in powerhouse channel. Of these, 11 were beached on the Washington shore and 23 were unaccounted for.
3/ Rate of travel not calculated because of late start.

Other observers left the dam at 9:00 a.m. in another boat, arriving at Ellsworth cannery, 33 miles below Bonneville, at noon. Floats were seen along the route for the first 15 miles below Bonneville and although observations were continued at Ellsworth cannery until 5:00 p.m., no floats were seen. Therefore, more than 16 hours were required for the floats to travel the 33 miles from Bonneville to the cannery.

At 2:11 p.m., the observers stationed at Cape Horn started back upstream and examined those sections of the Washington shore where dead fish had previously been found. They found 18 red-top and 11 white-top floats beached on the Washington shore between Cape Horn and Butler's Eddy, a point five miles below Bonneville, and 19 red-top floats between Butler's Eddy and Bonneville. We believe that 11 red-top and 23 white-top

floats unaccounted for went aground on the Oregon shore, which was not checked because of engine trouble in the boat. Two days later three white-top floats were found beached on the Washington shore just above Ellsworth cannery, but no floats were observed on the Oregon shore.

Observations of Dead Fish. Reports at various times had reached the U. S. Fish and Wildlife Service and the U. S. Corps of Engineers that great numbers of dead fish were floating below Bonneville Dam in the vicinity of Ellsworth cannery. We decided, therefore, to station observers at Ellsworth cannery on the day following the peak of the fall run of chinook salmon at Bonneville Dam (Appendix, Table 2), on the assumption that dead fish would appear in the river in greatest numbers during and following the time when the fish were most numerous at the dam. It had been determined from our recently completed float experiments that dead fish originating at Bonneville would drift downstream at about one and one-half miles per hour (Table 4), so that dead fish from the dam should cover the 33 miles to Ellsworth cannery in about 43 hours.

Salmon and trout sink immediately after death. Decomposition soon begins, causing gas to form within the body of the fish. When a sufficient quantity of gas has been formed, the carcass is buoyed up and floats, provided, of course, that the gas is trapped within the body of the fish. 1/

Dead Fish Below Bonneville. The Ellsworth cannery wharf was chosen for the place of observation because the main river channel touches the end of the wharf, and it is in this main channel that nearly all of the drift travels. Furthermore, the wharf is high enough above the water level that observers could readily see any floating fish that might pass. Two men were stationed at this point, one to watch for the floating fish and the other, in a power boat, to pick up the fish. The number of dead fish observed at this point is recorded in Table 5 and it can be seen that during 64 hours of observation covering a period of 8 days only 10 dead chinook salmon were observed. On September 18, the observers examined both shores by boat from Ellsworth, to Washougal, Washington; during seven hours of observations, no dead salmon or steelhead trout were observed. On September 19 the boat proceeded to Bonneville Dam and during the seven and one-half hours of travel time, three dead chinook salmon and one dead steelhead trout were observed.

1/ Observations made by Charles B. Wade, Aquatic Biologist, U. S. Corps of Engineers. The full text of his report is included in Appendix II.

Table 5. Number of dead chinook salmon and steelhead trout seen floating in the Columbia River by observers on the wharf of the Ellsworth cannery (approximately 30 miles below Bonneville dam) during the period September 10-17, 1946.

Date 1946	Period a.m	Period p.m	Hours	Chinook salmon	Steelhead trout
Sept. 10	7:00	3:30	8 1/2	0	0
11	8:00	4:00	8	1	0
12	8:00	4:00	8	1	0
13	8:00	4:00	8	1	0
14	8:00	4:00	8	3	0
15	8:30	4:30	8	2	0
16	9:00	4:30	7 1/2	1	0
17	8:00	4:00	8	1	0
Totals			64	10 1/	0 1/

1/ The average number of dead chinook salmon seen per hour during this period was 0.156. No dead steelhead trout were observed. The average for both species was 0.156 per hour, or 2.7 per day.

Observers with a boat were also stationed at Cape Horn, about halfway between the dam and Ellsworth to determine whether all of the floating fish drifted as far downstream as Ellsworth. During our observations on wood floats, it had been learned that practically all of the river drift at this point came within 100 feet of the Washington shore, making it very easy for an observer to see dead fish float by. As at Ellsworth, one man watched for the floating fish and the other picked up the fish from the boat. Here, however, to prevent duplication of count, the boatman tagged and replaced the fish in the river for possible later recovery at Ellsworth. Table 6 shows that during approximately 52 1/2 hours of observation spread over a 9 day period 11 chinook salmon and 3 steelhead trout were observed. None of the tagged fish were recovered below Cape Horn.

Table 6. Number of dead chinook salmon and steelhead trout seen floating in the Columbia River near Cape Horn (approximately 13 miles below Bonneville Dam) during the period September 10-19, 1946.

Date 1946	Period a.m.	Period p.m.	Hours	Chinook salmon	Steelhead trout
Sept. 10	8:00	2:00	6	1	0
11	7:45	2:05	6-4/12	2	0
12	7:45	2:00	6-3/12	5	0
13	8:00	1:45	5-9/12	0	1
15	9:00	1:00	5	1	1
16	7:55	1:55	6	2	0
17	8:50	1:45	5	0	0
18	7:55	2:10	6-3/12	0	0
19	7:30	1:30	6	0	1
Totals			52-7/12	11 1/	3 1/

1/ The average number of dead chinook salmon seen per hour during this period was 0.209 and the average number of dead steelhead trout seen per hour was 0.057; the average for both species was 0.266 per hour. This would average 6.4 fish per day. During this period, 16 to 18 sturgeon fishermen between Bonneville and Cape Horn were using 10 to 20 dead salmonoid fish per day for bait.

En route to Cape Horn and during the subsequent return trip to the dam, the observers picked up a few beached dead fish. These are recorded in Table 7.

Table 7. Number of dead chinook salmon and steelhead trout found floating in the river or beached on the Washington shore between Bonneville Dam and Cape Horn during the period September 10-18, 1946

Date 1946	Chinook salmon	Steelhead trout
Sept. 10	0	0
11	2	0
12	6	1
13	0	1
14	0	0
15	0	0
16	2	0
17	1	0
18	0	0
Totals	11	2

U. S. Coast and Geodetic Survey charts for the Columbia River from Vancouver, Washington, to The Dalles, Oregon have been reproduced in Figures 8 and 9, and have been marked off in 1-mile sections from The Dalles, Oregon, to Lyle, Washington, and from Bonneville Dam to Cape Horn, Washington. The numerals in the circles refer to the numbers of dead fish found in each 1-mile section. Only fish found in 1946 during the period of the fall run are included in the figures encircled. Figure 8 also includes 21 dead salmon and steelhead trout which were picked up just below the spillway section on September 6 and October 3, 1946.

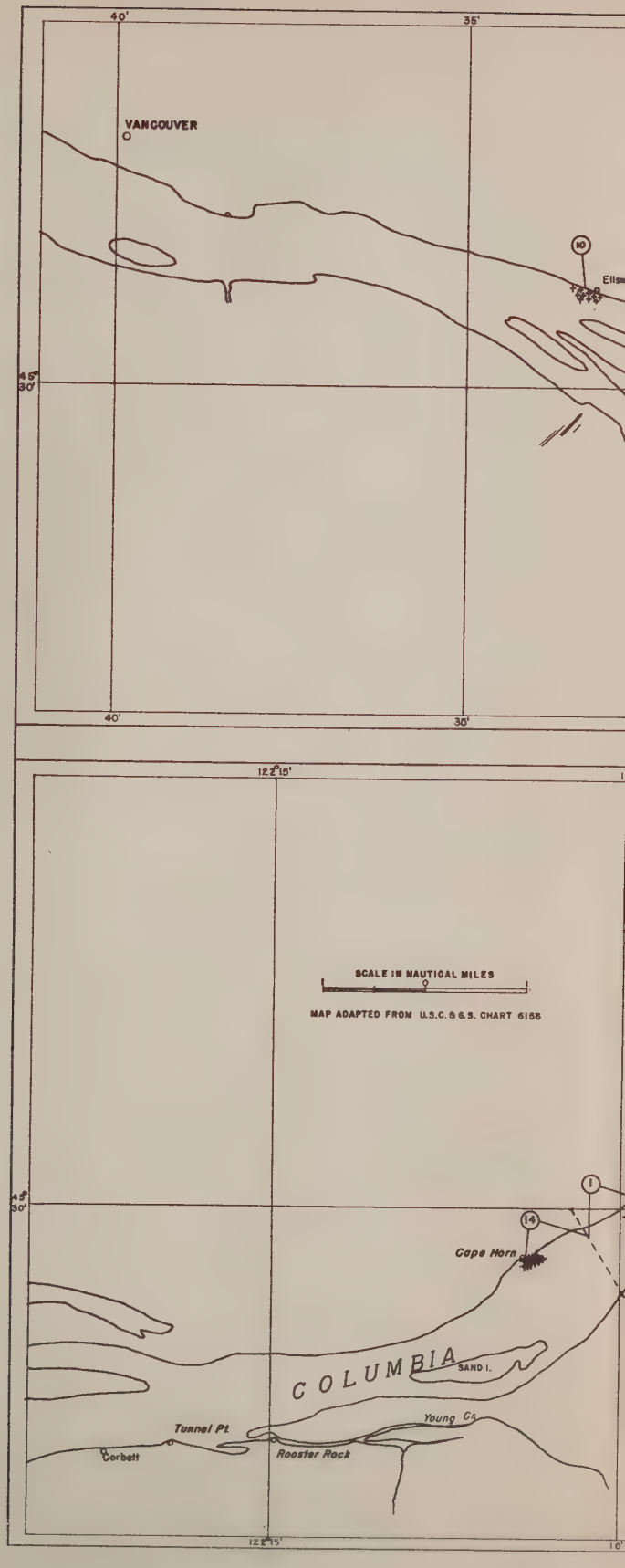
Dead Fish Above Bonneville. It was decided to conduct the same intensive search for dead fish above Bonneville Dam as below in order to compare the rate of mortality of fish that had passed over Bonneville Dam with those that had not surmounted the ladders. Accordingly, observers were stationed at The Dalles, Oregon, from September 10 to 19, inclusive. With the aid of a power boat, these men made a search for dead fish between The Dalles, Oregon, and Lyle, Washington. The section of river near The Dalles is roughly the same distance below Celilo Falls, a natural barrier, as Cape Horn is below Bonneville Dam, an artificial structure. Figure 9 shows the distribution of the fish found.

Table 8 shown that in 81-1/2 hours of observations 93 dead salmon and steelhead were found. On September 23, the boat returned to the dam. En route to the dam 11 dead chinook salmon were found during 5 hours of observation.

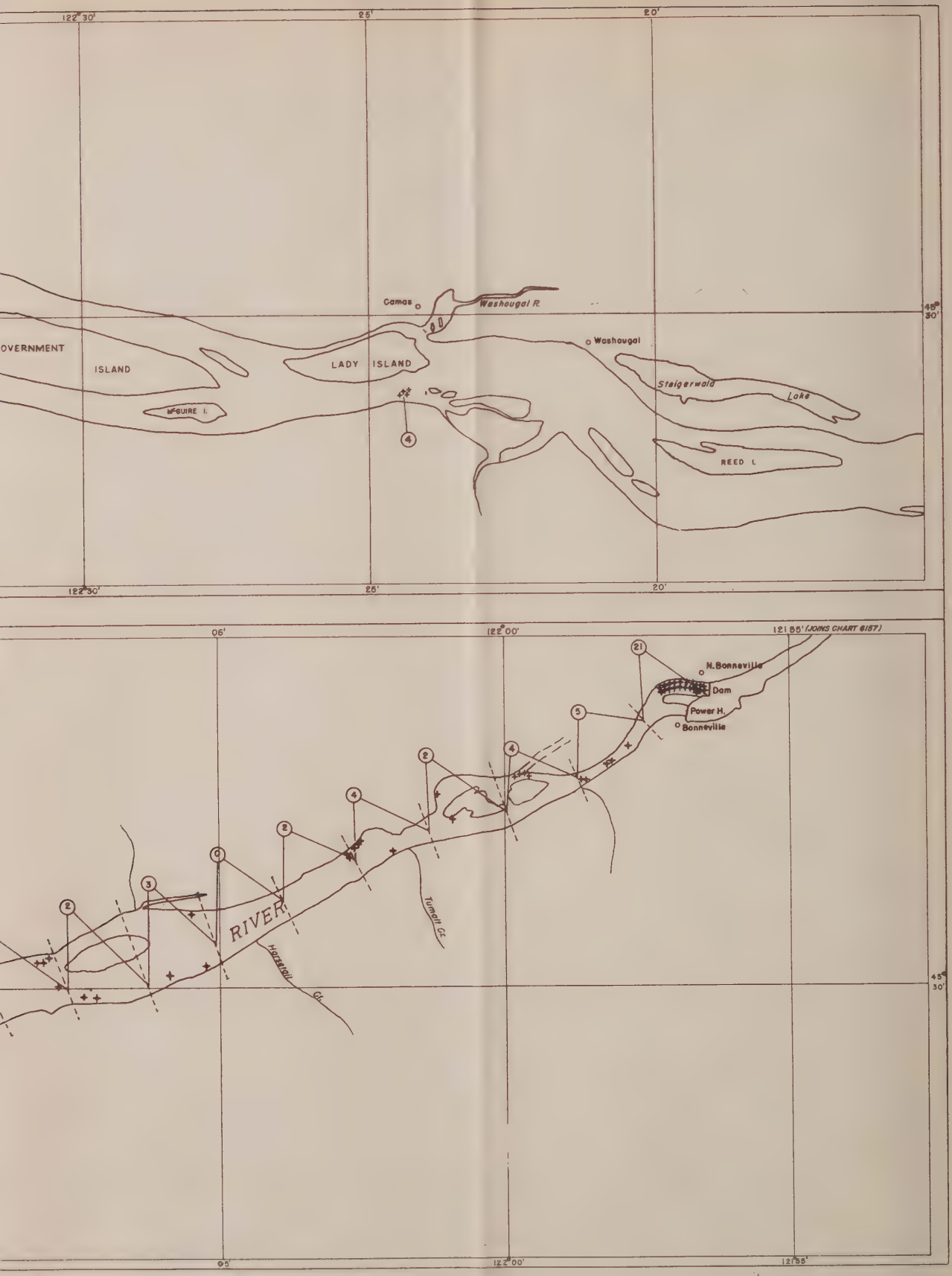
Table 8. Number of dead chinook salmon and steelhead trout seen floating in the Columbia River in the vicinity between The Dalles, Oregon, and Lyle, Washington, (approximately 13 miles below Celilo Falls) during the period September 10-20, 1946.

Date 1946	Period a.m	Period p.m	Hours	Chinook salmon	Steelhead trout
Sept. 10	8:00	4:30	8 1/2	4	2
11	8:00	4:30	8 1/2	0	0
12	8:00	4:30	8 1/2	13	2
13	8:00	4:30	8 1/2	11	0
14	8:00	12:30	4 1/2	2	0
15	8:00	4:30	8 1/2	8	1
16	8:00	4:30	8 1/2	9	1
17	8:00	4:30	8 1/2	6	0
18	8:00	4:30	8 1/2	19	3
19	8-11	1-5	7	11	1
20	9-11	--	2	0	0
Totals			81 1/2	83 1/	10 1/

1/ The average number of dead chinook salmon seen per hour during this period was 1.018, and the average number of dead steelhead trout seen per hour was 0.123; the average for both species was 1.41 per hour. This would average 27.4 fish per day. During this period approximately 15 sturgeon fishermen were fishing between Celilo Falls and the point of observation. However, most, if not all, of these men used lamprey or smelt for bait.


40'
35'
VANCOUVER
45°
30'
40'
30'
122°15'
SCALE IN NAUTICAL MILES
MAP ADAPTED FROM U.S.C. & G.S. CHART 6155
45°
30'
14
Cape Horn
COLUMBIA
SAND I.
Young Cr.
Tunnel Pt.
Corbett
Rooster Rock
122°15'

Figur



- Approximate location and number of dead fish found between Bonneville Dam and Cape Horn, Washington, 1946.

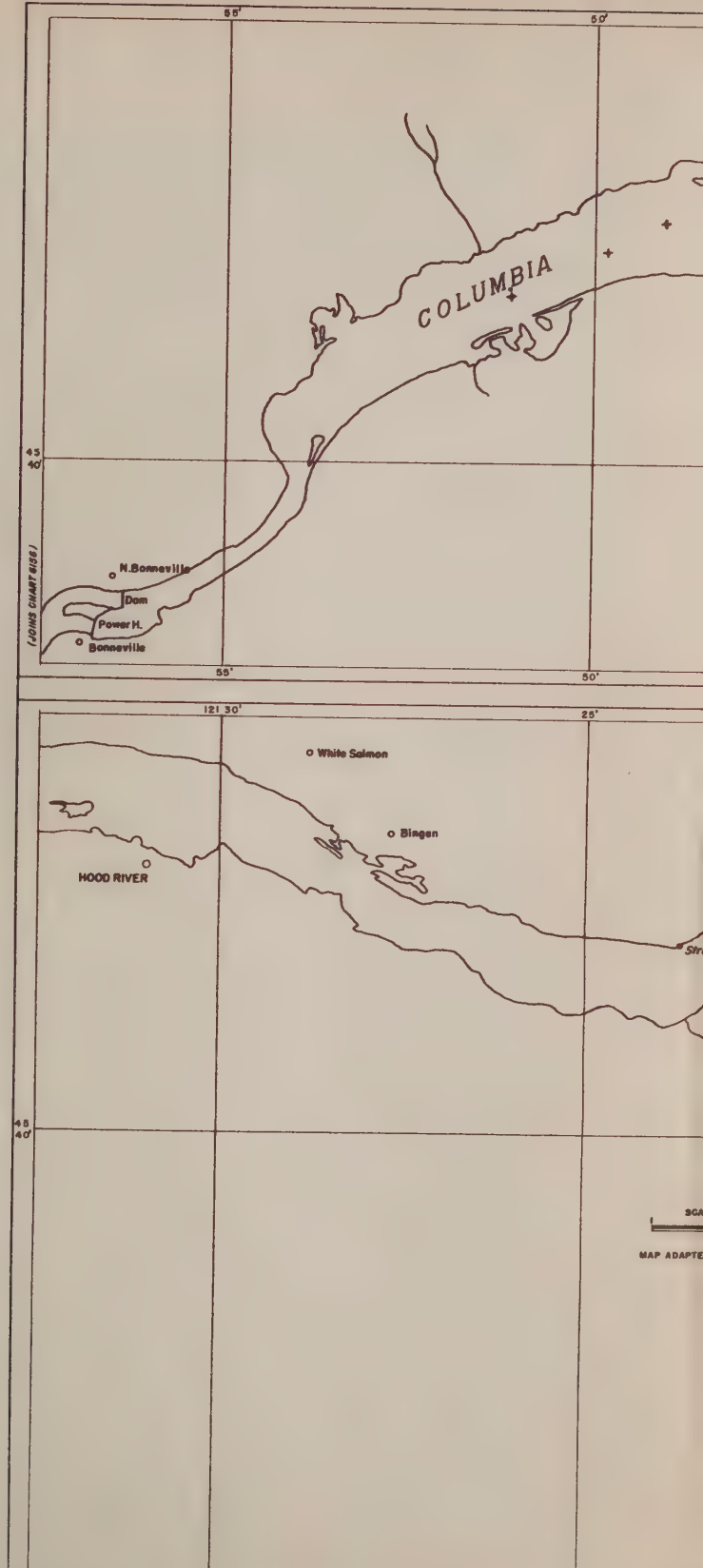
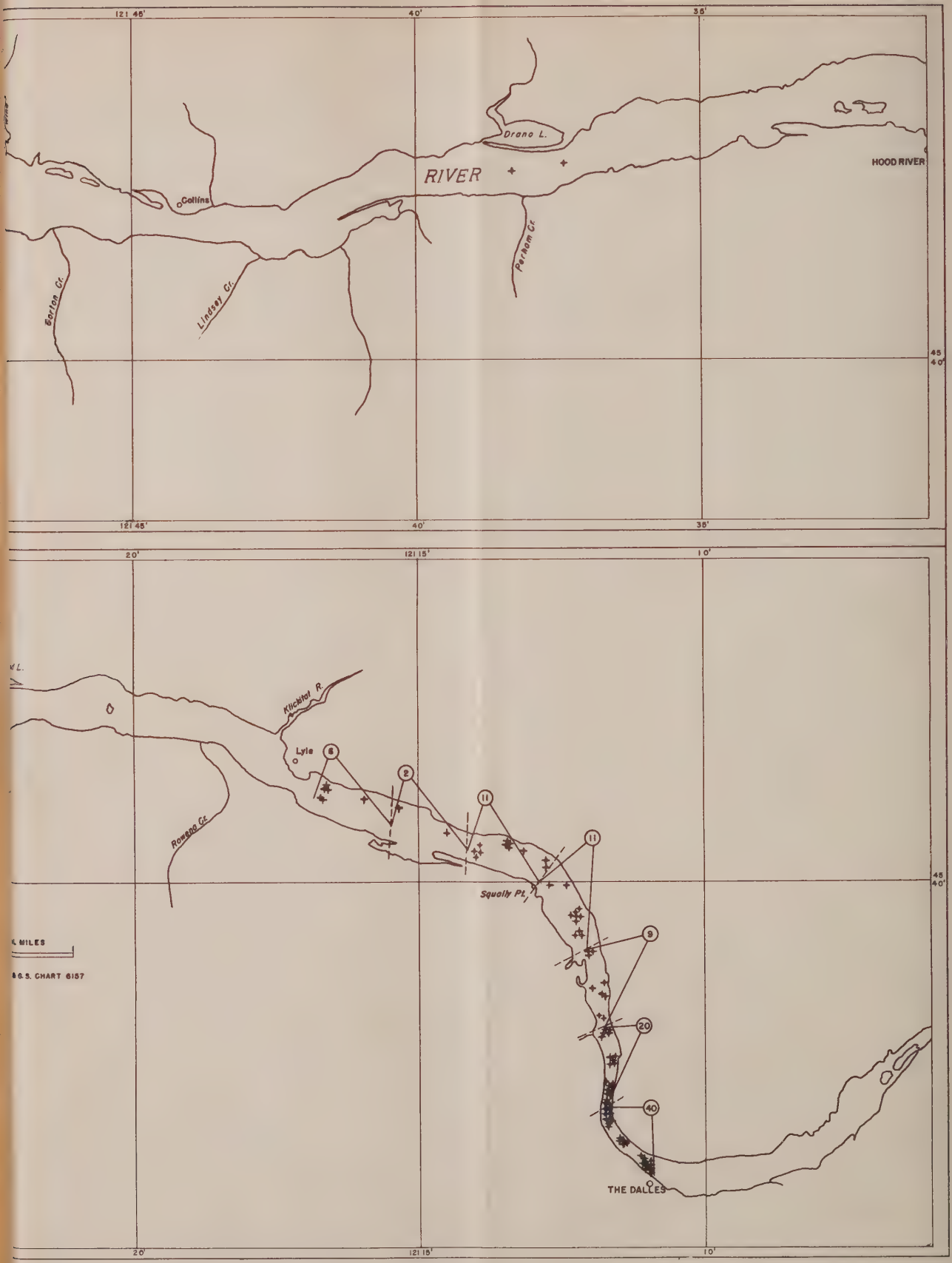

55'
50'
COLUMBIA
45
40'
N.Bonneville
Dam
Power H.
Bonneville
(JOHNS CHART 6158)
55'
50'
121 30'
25'
White Salmon
Bingen
HOOD RIVER
45
40'
121 30'
25'

Figure 9



Approximate location and number of dead fish found between Bonneville Dam and The Dalles, Washington, 1946.

Dead Fish Used by Sturgeon Fishermen. It is the practice of many Columbia River sturgeon fishermen, above and below Bonneville Dam, to pick up floating dead salmon and use them for bait. In order that the record of dead fish in August and September 1946 might be made as complete as possible and to try to adjust our observations by allowing for dead fish thus used, we decided to interview as many of these fishermen as we could reach.

The fishermen fishing for sturgeon below the dam reported that one or two dead salmon per man were picked up each day during the period August 15 to September 15. As far as could be determined, there were only ten fishermen who used floating dead salmon; the other six or eight used either lamprey or smelt for bait. It might, therefore, be assumed that ten dead fish were picked up each day from mid-August to mid-September by sturgeon fishermen below the dam.

A commercial fisherman who fishes for sturgeon in the vicinity of The Dalles, Oregon, 50 miles above the dam, stated he had seen about ten "floaters" (dead salmon) per day during the period August 15 to September 15, 1946. He did not remove the fish from the water. According to his further statement, there were in September about 15 men fishing for sturgeon between Lyle and Celilo Falls. He further stated that only one or two fishermen above the dam used dead salmon for bait and that most of the hook-and-line fishing is done using lamprey or smelt as bait.

SUMMARY

1. An incomplete record of mortality of adult salmon and steelhead trout occurring in the Columbia River at Bonneville Dam and for a distance of several miles below the dam has been kept by the U. S. Corps of Engineers each year since the dam was completed in 1938 (Appendix, Table 1-8).

2. Fish counters at Bonneville Dam kept incomplete records of the injured fish passing over the counting boards in the fish ladders. Observations were conducted in May 1943 and during June, July, and August 1946. No attempt was made to record the total number of injured fish as compared with the total number of fish passing the counting boards. Instead, however, injuries were recorded for only a portion of each day's run. A continuous abrasion which extended from the back to the belly was tabulated as a net injury. Often wounds or cuts along the body or head were listed as other injuries. Since a counter could observe only one side of a fish as it swam over the board, the numbers of injured fish seen were doubtless less than the total number of injured fish passing. In 1946, 6.4 percent of the number of fish in the samples observed showed net injuries and approximately 3.7 percent showed injuries attributed to other causes.

3. A comparison was made between the numbers of injured fish appearing in the adult chinook salmon run arriving at Big White Salmon Hatchery, about 30 miles above Bonneville Dam, and at Bonneville Hatchery, about one mile below Bonneville Dam. No great difference was found to exist in the percent of injured fish at the two locations. For example, 23 percent of the fish examined at Big White Salmon Hatchery had dorsal-fin abrasions, and slightly more, or 26.5 percent, of the fish below the dam at Bonneville Hatchery had similar injuries. These injuries were undoubtedly caused by fishermen's nets. Other types of injuries, the origin of which is not known, occurred in 1.7 percent of the salmon examined at Big White and 2.4 percent of the salmon examined at Bonneville station.

4. A submersible observation chamber was constructed by the U. S. Corps of Engineers for the purpose of directly observing and making a photographic record of the action of salmon passing through submerged orifices in one of the fish ladders at Bonneville Dam. Neither the direct observations nor the moving picture records showed fish being injured in ladder.

5. One hundred wood floats, simulating floating dead salmon, were released at Bonneville Dam to determine the time required for fish that might die at Bonneville to be carried downstream past Ellsworth cannery. On August 28, 1946, when the river was flowing 92,000 cubic feet per second, the average rate of flow of the river was found to be between 1.03 and 1.61 miles per hour. Therefore, floating dead fish at Bonneville Dam should drift by Ellsworth cannery (33 miles below) about 43 hours after leaving the dam. Since about 72 hours are required for salmon to be buoyed up sufficiently to be carried by the current,* the total time elapsing between the death of a fish at Bonneville and its appearance as a floating carcass at Ellsworth should be approximately 115 hours.

6. A count of the numbers of floating dead salmon above and below Bonneville Dam was made during the peak of the fall run in 1946. During 64 hours of observations over an 8-day period, 10 dead salmon were seen floating by Ellsworth cannery, and 3 dead salmon and one dead steelhead were observed en route to Bonneville Dam from Ellsworth on September 18 and 19. Fourteen dead salmon and steelhead were recorded and tagged as they passed Cape Horn (about 13 miles below Bonneville). These fish were not observed at Ellsworth, Washington. In addition to the fish floating past Cape Horn, the observers noted 13 dead fish beached on the shore between Cape Horn and Bonneville Dam. Thus, in about 72 hours of search between the dam and Cape Horn, 27 dead fish were counted. Above Bonneville Dam, the observers saw 104 dead fish in about 86.5 hours of intensive search during the same period.

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*Wade, 1945, see Appendix.

CONCLUSIONS

1. The great numbers of dead fish reported in previous years below Bonneville Dam did not appear in 1946 during the period of investigation.

2. Floating dead fish were found in about the same numbers above and below Bonneville Dam.

3. Injured fish were found at Bonneville Hatchery below Bonneville Dam and at Big White Salmon Hatchery above the dam in approximately the same proportions.

4. Most injuries to the fish observed are traceables to fishermen's gill nets; none of the injuries were directly traceable to conditions at Bonneville Dam.

5. Most net injuries were not fatal to fall-run chinook salmon at hatcheries above and below Bonneville Dam in 1946.

APPENDIX

TABLE 1

RIVER FLOW IN CUBIC FEET PER SECOND - BONNEVILLE DAM
August 1 - September 15, 1946

Date	Flow	Date	Flow
August		September	
1	225,000	1	117,000
2	212,000	2	115,000
3	193,000	3	102,000
4	191,000	4	102,000
5	184,000	5	100,000
6	173,000	6	99,000
7	174,000	7	110,000
8	189,000	8	95,000
9	191,000	9	112,000
10	142,000	10	109,000
11	130,000	11	109,000
12	160,000	12	110,000
13	151,000	13	112,000
14	144,000	14	112,000
15	140,000	15	109,000
16	139,000		
17	161,000		
18	113,000		
19	134,000		
20	117,000		
21	114,000		
22	117,000		
23	102,000		
24	101,000		
25	111,000		
26	95,000		
27	92,000		
28	92,000		
29	87,000		
30	89,000		
31	97,000		

APPENDIX

TABLE 2

BONNEVILLE COUNT-CHINOOK, STEELHEAD, BLUEBACK, AND SILVER SALMON

FOR YEARS AND MONTHS DURING WHICH DEAD FISH OBSERVATIONS WERE CONDUCTED

Date	Species of Anadromous Fish			
1938	Chinook	Steelhead	Blueback	Silver
August	34,765	29,231	2,097	3,070
September	197,294	46,618	235	10,995
1939	Dead fish studies were not conducted this year.			
1940				
July	14,938	61,171	85,885	--
August	58,643	46,071	3,063	1,451
September	240,500	64,377	11	10,165
October	3,765	1,786	1	213
1941				
April	51,486	6,392	299	--
May	19,445	1,518	1,052	--
June	7,013	994	23,536	--
July	9,395	21,940	39,193	--
August	12,590	29,600	1,615	1,317
September	351,967	50,542	46	16,061
October	7,179	3,980	--	369
1942				
June	11.816	1,588	12,624	--
July	12,821	19,905	41,301	--
August	27,581	41,973	1,477	1,193
September	303,995	76,622	49	11,061
1943				
June	5,440	1,564	4,525	--
July	8,044	7,755	33,613	--
August	28,985	29,894	1,697	762
September	201,414	41,051	1	1,676
October	3,354	2,444	89	125

APPENDIX

TABLE 2 Cont'd.

1944	Chinook	Steelhead	Blueback	Silver
May	15,127	2,227	16	--
June	4,363	1,169	3,098	--
July	8,241	21,868	11,171	--
August	55,468	24,508	659	1,052
September	139,254	35,907	126	3,021
1945				
July	16,327	24,600	6,903	2
August	32,254	40,483	498	239
September	189,675	40,194	10	533
1946				
April	14,179	9,839	9	--
May	53,313	5,481	67	--
June	30,051	3,265	7,805	--
July	20,960	20,559	64,704	22
August	45,421	58,356	1,746	227
September	277,075	38,296	21	3,609

TABLE 3

DEAD SALMON AND STEELHEAD TROUT FOUND

BETWEEN BONNEVILLE DAM AND MULTNOMAH FALLS

1938 - 1946

Date	Location	Total Dead Fish	Total Hours Observation
1938		187	24
1939*			
1940		226	88
1941		561	208
1942		142	72
1943		320	96
1944		19	48
1945		192	104
1946		102	168

*No dead fish observations.

APPENDIX

TABLE 4

RECORD OF DEAD FISH FOUND

COLUMBIA RIVER BONNEVILLE DAM - MULTNOMAH FALLS

August - September, 1938

Date	Species				Total	Monthly Total
	Chinook	Steelhead	Blueback	Silvers		
1938						
August 8	4	-	-	-	4	4
September 6	94	1	-	-	95	
10	88	-	-	-	88	187

TABLE 5

RECORD OF DEAD FISH FOUND

COLUMBIA RIVER BONNEVILLE DAM - MULTNOMAH FALLS

July - October, 1940

Date	Chinook	Steelhead	Blueback	Silvers	Total	Monthly Total
1940						
July 8	7	-	-	-	7	7
September 4	42	-	-	-	42	
6	6	-	-	-	6	
12	19	2	-	-	21	
14	6	1	-	-	7	
17	16	2	-	-	18	
18	28	11	-	1	40	
19	1	-	-	-	1	
20	16	5	-	-	21	
25	59	2	-	-	61	217
October 10	2	-	-	-	2	2

APPENDIX

TABLE 6

RECORD OF DEAD FISH FOUND

COLUMBIA RIVER BONNEVILLE DAM - MULTNOMAH FALLS
April - October, 1941

Date 1941		Species: Chinook	Steelhead	Blueback	Silvers	Total	Monthly Total
April	17	3	-	-	-	3	
	24	3	-	-	-	3	6
May	1	27	-	-	-	27	
	8	11	1	-	-	12	
	15	15	-	-	-	15	
	22	17	1	-	-	18	72
June	5	7	-	-	-	7	
	12	7	2	1	-	10	
	19	8	-	2	-	10	
	26	11	1	3	-	15	42
July	3	21	1	2	-	24	
	10	21	3	2	-	26	
	17	8	3	2	-	13	
	24	10	10	5	-	25	
	31	7	2	1	-	10	98
Aug.	7	-	2	-	-	2	
	14	2	4	-	-	6	
	21	1	1	-	-	2	
	28	2	6	-	-	8	18
Sept.	4	28	3	-	1	32	
	11	83	14	-	-	97	
	18	128	9	-	4	141	
	25	19	2	-	-	21	291
Oct.	2	19	4	-	-	23	
	9	10	-	-	-	10	
	17	1	-	-	-	1	34

APPENDIX

TABLE 7

RECORD OF DEAD FISH FOUND

COLUMBIA RIVER BONNEVILLE DAM - MULTNOMAH FALLS
June - September, 1942

Date		Species: Chinook	Steelhead	Blueback	Silvers	Total	Monthly Total
1942							
June	23	-	-	-	-	0	0
July	2	10	-	3	-	13	
	9	14	1	7	-	22	
	16	6	1	2	-	9	
	23	6	-	-	-	6	
	30	6	3	-	-	9	59
Aug.	3	7	-	-	-	7	
	6	4	2	-	-	6	13
Sept.	10	26	3	-	-	29	
	17	38	3	-	-	41	70

TABLE 8

RECORD OF DEAD FISH FOUND

COLUMBIA RIVER BONNEVILLE DAM - MULTNOMAH FALLS
June - October, 1943

Date		Species: Chinook	Steelhead	Blueback	Silvers	Total	Monthly Total
1943							
June	16	2	-	-	-	2	
	19	4	-	-	-	4	
	26	3	-	-	-	3	9
July	2	4	-	-	-	4	
	16	4	1	1	-	6	
	26	5	-	-	-	5	15
Aug.	8	13	1	1	-	15	
	16	7	1	-	-	8	
	27	1	-	-	-	1	24
Sept.	9	146	9	-	1	156	
	20	60	-	-	-	60	216
Oct.	2	52	4	-	-	56	56

APPENDIX

TABLE 9

RECORD OF DEAD FISH FOUND

COLUMBIA RIVER BONNEVILLE DAM - MULTNOMAH FALLS
May - September, 1944

Date	Species				Total	Monthly Total
1944	Chinook	Steelhead	Blueback	Silvers		
May 29	2	-	-	-	2	2
June 7	1	-	-	-	1	
14	-	-	-	-	-	1
July 6	1	2	2	-	5	5
Aug. 4	1	1	-	-	2	2
Sept. 5	7	2	-	-	9	9

TABLE 10

RECORD OF DEAD FISH FOUND

COLUMBIA RIVER BONNEVILLE DAM - MULTNOMAH FALLS
July - September, 1945

Date	Species				Total	Monthly Total
1945	Chinook	Steelhead	Blueback	Silvers		
July 10	11	1	1	-	13	
17	13	8	-	-	21	
25	4	8	-	-	12	
31	4	5	-	-	9	55
Aug. 7	-	3	-	-	3	
14	1	-	-	-	1	
20	1	-	-	-	1	
29	2	1	-	-	3	8
Sept. 10	1	-	1	-	2	
18	77	4	-	-	81	
19	31	10	-	-	41	
26	5	-	-	-	5	129

APPENDIX

TABLE 11

RECORD OF DEAD FISH FOUND

COLUMBIA RIVER BONNEVILLE DAM - MULTNOMAH FALLS
April - October, 1946

Date 1946		Species: Chinook	Steelhead	Blueback	Silvers	Total	Monthly Total
April	25	2	-	-	-	2	2
May	3	5	-	-	-	5	
	9	4	-	-	-	4	
	16	-	-	-	-	-	
	23	5	-	-	-	5	14
June	10	2	-	-	-	2	
	20	6	-	-	-	6	8
July	11	16	2	6	-	24	
	16	6	2	2	-	10	
	24	7	7	3	-	17	51
Aug.	2	2	1	-	-	3	
	8	1	5	-	-	6	
	12	1	2	-	-	3	12
*Sept.	6	16	2	-	-	18	18
Oct.	3	6	-	-	-	6	6

* Dead fish found September 10-19 are recorded in the text, page 30 and are not included here.

APPENDIX I

C O P Y October 8, 1946

Memorandum

To: F. M. Lewis

Subject: Fishway Observation

There has recently been constructed an inspection chamber or diving bell for use in observing aquatic conditions in the fishway system.

Completion of the chamber was too late to make as thorough a study as might be desirable, but did give certain desirable information.

1. It was the consensus of the opinion that fish are not being injured passing through underwater orifices. Although there appears to be a fairly rapid velocity which requires some effort on the part of the fish to get through, it in no way taxes their capacity.

2. Fish do, at times, rub the top and sides of orifice, but several different observers agree they saw no fish passing through which, in their opinion, rubbed hard enough to be injured. From my own personal observation, I am not prepared to say definitely that fish are not, in some instances, injured. But for reasons other than injuries, I am of the opinion that underwater orifices are of no help to the fish.

3. The first setting of chamber was just upstream of Weir 68. This weir forms the lower end of stilling pool below counting station. Visibility varied during observation from excellent to fair. During the time of best visibility conditions, fish were very numerous, and could readily be observed as far as 15'-0" feet away. Water conditions could hardly be improved upon in this pool. As thousands were passing up the ladder, it was possible to observe their general condition and actions.

The opinion of all observers is that fish, upon reaching this pool, are inclined to take it easy, probably resting. They are in no apparent hurry and in contrast to those fish seen on the surface of the pool, those in the lower depths are remarkably calm and lazy. They displayed no concern over chamber, and many were curious enough to remain within inches of the windows for considerable periods of time.

4. Diver's underwater lights (1000 Watts) were used at times to light up the area adjacent to the orifice and chamber. The fish were in no way disturbed. Some even appeared to be fascinated by the lights and remained under the lights for minutes at a time. This would tend to disprove the idea that fish will not

cross counting board when lights are on. My own opinion is that it is a combination of white board and bright lights. My theory is the kick back or reflection from the board rather than the lights, is the cause of the turn backs. It is possible that all turn backs are females, exercising a woman's perogative.

5. After observing conditions in stilling pool water, the chamber was shifted to Weir 65 where water conditions are typical of the ladders as a whole. The chamber was first placed upstream of the weir, later downstream. As was anticipated, entrapped air greatly handicapped observations. Fish were observed coming through, but indistinctly, and detail was lacking, although all observers were agreed the velocity through opening appeared less then Weir 68 (lower end of the stilling pool). However it was proved that entrapped air does go to the bottom of the pool.

SUMMARY

1. Consensus of opinion by observers is that injury just forward of dorsal fin frequently observed by counters is not caused by underwater orifices. This opinion is substantiated by observing fish in after bay below power house. The fish clearly visible in tailwater were observed to be marked before entering ladders.

The fish entering Bonneville Hatchery were also observed and the same condition noted in about the same quantities as seen in the ladders.

Most logical opinion expressed so far is, fish escaping from the nets are injured in the process of doing so.

2. My objection to orifices is, no place for fish to rest.

Lack of any deposit of silt or debris indicates no still water in pools.

From an operational standpoint they are excellent and very desirable.

3. Stilling pool below counting station is desirable so far as allowing fish to rest.

That water below top of weir is practically free of current, and fish move and maintain themselves with a minimum amount of effort. At times there appears on the surface a great number of fish that would indicate congestion, but underwater observation proves this apparent congestion to be not true.

4. Artificial lights no detriment.

5. Entrapped air does permeate all areas of ladders. The entrapped air appears in the shape of rather large air bubbles, very different than surface conditions would indicate.

Continued observations during the coming year is anticipated.

/s/ F. A.
F. L. Abbott

"U.S. Engineer office
Oct 14 8 25 AM '46
Portland, Oregon"

APPENDIX II

WAR DEPARTMENT
Portland, Oregon District
Office of the Area Engineer

Bonneville, Oregon
28 August 1945

Subject: Tests to Determine the Time Factor in the Floating of Dead Salmonoid Fishes, Bonneville Dam, 1945.

To: Captain R. B. Cochrane, Resident Engineer, Bonneville, Oregon.

INTRODUCTION

It is evident from weekly patrols by boat on the Columbia River below Bonneville Dam, that some losses in salmonoid fishes occur either at Bonneville or in its vicintiy. During the past years some information has been gathered on the numbers of dead fish found below Bonneville. This information seems to be of very little value, other than on a certain date so many fish were recovered from within a certain area of the river and its bank. Such information does not lend itself to an analysis of the fish losses occurring at Bonneville. Only after a complete study of the many biological and physical factors involved will it be possible to ascertain the effect, if any, which Bonneville Dam has upon fish fatalities. Also it may be pointed out that only after such knowledge is available can the proper remedial measures be taken.

After examining many dead salmon below Bonneville, it became apparent that some knowledge of the relationship between the physical appearance of the fish and the length of time that it had been dead would be very helpful in studying the downstream drift and other factors. Even a rough approximation of how long the fish had been dead would perhaps yield some clue as to where it was killed. This test to determine the time factor in the floating of dead salmon is but a small part of the work needed to be done. Additional observations upon the progressive changes in physical appearance of the dead fish were made and are included in this report.

METHODS

Before beginning the tests, it was realized that it would be necessary to confine the fish in some manner, so that periodic examinations could be made. Obviously, this is not the normal conditions to which the natural river losses would be subjected, but it was believed that conditions would not be sufficiently different to affect the results. It was decided to confine the fish in large meshed bags and to tether them to the shore. In the actual test this method proved satisfactory and the alternate method of placing them in a wire cage was not used.

Bags of No. 32, soft laid seine twine were made up in both 4- and 6-inch stretch mesh, of which the 4-inch mesh proved to be the most satisfactory. The bags were made large enough and long enough to accommodate the largest fish used, and the excess length disposed of when smaller specimens were used. The greater circumference of the bags did not seem to hinder the holding of the smaller fish.

The desired specimens were secured at the Washington Shore trap, and killed with the least possible damage to the fish. The specimens were immediately placed in their bags and deposited in the holding area located along the Bradford Island side of the spillway forebay. The holding area was not only accessible, but provided water of sufficient depth and quietness to carry on the work. Total lengths of the specimens were taken, and the time they were placed in the water noted. Observations were made on the length of time it took them to float, how many floated, and how long they remainded at the surface. Notes were also kept on the physical appearance of the dead fish. The test was carried out a second time to check the results of the first test.

OBSERVATIONS

Part 1

In this part of the tests, 11 chinook salmon were used. The essential information is found in the following table:

Specimen	Total Length	Placed in Water	Found Floating	Found on Bottom	Time Required to Float (in hours)	No. of hrs. Floated
1	1'8 1/2"	3:00 pm 18 July	2:00 pm 21 July	4:00 pm 27 July	71	146
2	2'3"	3:00 pm 18 July	2:00 pm 21 July	3:30 pm 30 July	71	217 1/2
3	2'3 1/2"	3:00 pm 18 July	2:00 pm 21 July	4:00 pm 1 August	71	266
4	1'10"	3:00 pm 18 July	8:15 am 23 July	5:00 pm 29 July	113*	152 3/4
5	1'10 1/8"	3:00 pm 18 July	2:00 pm 21 July	3:30 pm 28 July	71	165 1/2
6	1'9 1/2"	3:00 pm 18 July	2:00 pm 21 July	3:30 pm 28 July	71	165 1/2
7	1'9"	3:00 pm 18 July	2:00 pm 21 July	8:15 am 23 July	71**	42***
8	1'9"	2:00 pm 19 July	8:15 am 23 July	5:00 pm 29 July	90	153

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Specimen	Total Length	Placed in Water	Found Floating	Found on Bottom	Time Required to Float (in hours)	No. of hrs. Floated
9	2'9 1/4"	1:45 pm 20 July	8:15 am 23 July	4:00 pm 31 July	66	199 3/4
10	1'9"	3:30 pm 20 July	8:15 am 23 July	8:15 am 1 August	65	264
11	1' 9 1/2"	3:30 pm 20 July	2:30 pm 23 July	4:00 pm 3 August	71	193 1/2

(*) This specimen was almost floating at 2:00 pm 21 July. Circumstances made observations impossible on 22 July, and it is probable this fish floated up on that date or the evening of the day before.

(**) Specimen 7 only partially floated to the surface, head up, body down. Was never observed floating flat on the surface.

(***) Specimen 7 sank to bottom in a short time. Pulled to surface and examined, and was found to have one side of abdomen partly burst or eaten out.

On 19 July observations were made on the physical appearance of specimens 1, 2 and 3 at the end of 24 hours. These fish looked as if they were freshly killed; their color was only slightly faded and the gills were still slightly pink. The body had become rigid and the flesh remained firm. There was no external sign of bloat in the abdominal region. The paired fins were not frayed and still lay close to the sides of the body. On 20 July specimen 8, which had been dead for 26 hours, was examined, and in general the appearance was similar to that observed with the first 3 specimens examined, the only noticeable difference being that there was slight evidence of bloat around the posterior part of the abdominal cavity. All specimens sank readily when returned to the water.

At the end of 48 hours, specimens 1, 2, and 3 were re-examined. The color was fading badly, becoming mottled in appearance, and the gills were entirely bleached out, but not deteriorated. The paired fins lay normally along the sides of the body, and were not frayed or torn. The skin was not broken and still clear of any coating of slime. The flesh was moderately soft to the touch, and the body had become slightly flexible. A slight bloat was evident in the abdominal region, and the abdominal walls were firm and hard, but not greatly distended. A slight but definite odor of putrification was evident. When returned to the water, they sank readily to the bottom.

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On 21 July observations were made on the appearance of the fish floating on the surface. The fish lay on their sides in the water, with the belly slightly higher than the back. The abdominal cavity was well distended with gas, appearing puffed out posteriorly. The paired fins extended straight out from the sides of the body, evidently forced into that position by the pressure of gas inside the body. The surface of the skin was soft and dull, and the flesh soft and spongy. There were no marks or broken skin on the body. A strong and definite odor of decaying fish was present. The fish were again checked on the morning of 23 July; the side of the fish floating upward had turned brown (sunburnt) from exposure to the sun and air. The skin was leathery and wrinkled, and cracked when the fish was bent. The head and tail regions were beginning to develop a fungus growth. External evidence of bodily deterioration was beginning to show at base of anal fin and around anal opening. The skin had burst and the flesh beneath was exposed. The fins were becoming frayed and torn. The body was limp and the flesh soft and pulpy. A very strong odor was present.

From this time on, until the fish finally sank, their condition became progressively worse. It would be very difficult, if not impossible, to even approximately define their physical appearance at any definite time, during this period, since it was characterized by the continued growth of fungus on the body and the rapid deterioration of the entire fish. Evidently the internal structures were entirely decomposed for the fish floated as limply as a rag in the water. It seemed evident that the fish was held together by the skin. By the time they were ready to sink, only a slight agitation was needed to break them up.

Part 2

The second test was made partly to confirm the results of the first test, and to see if there were any great difference in other species. In the following table, specimens 1 to 4 are chinook, specimen 5 a blueback, and specimens 6 to 10 steelhead.

Specimen	Total Length	Placed in Water	Found Floating	Found on Bottom	Time Required to Float (in hours)	No. of hrs. Floated
1	1'7"	2:00 pm 26 July	5:00 pm 29 July	4:00 pm 31 July	75	47
2	1'10"	2:00 pm 26 July	5:00 pm 29 July	6:15 pm 5 August	75	169 1/4
3	2'1"	2:00 pm 26 July	5:00 pm 29 July	2:00 pm 6 August	75	189
4	1'5"	3:15 pm 26 July	5:00 pm 29 July	4:00 pm 31 July	73 3/4	47
5*	1'9 1/2"	3:15 pm 26 July	3:30 pm 28 July	4:00 pm 7 August	48	240 1/2

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Specimen	Total Length	Placed in Water	Found Floating	Found on Bottom	Time Required to Float (in hours)	No. of hrs. Floated
6	1'11"	4:00 pm 26 July	5:00 pm 29 July	6:15 pm 5 August	73	169 1/2
7	1'8"	4:00 pm 26 July	4:00 pm 31 July	2:00 pm 6 August	120	142
8	1'11 1/2"	4:00 pm 26 July	3:30 pm 30 July	4:00 pm 7 August	95 1/2	192 1/2
9	2'1"	4:00 pm 26 July	3:30 pm 30 July	2:00 pm 6 August	95 1/2	166 1/2
10	2'	4:00 pm 26 July	5:00 pm 29 July	9:00 pm 4 August	73	136

(*) The blueback had been injured. A circular area 2 1/2 inches in diameter from which the skin had been abraded was present on the right side of the body.

Observations similar to those in Part 1 were made on the physical appearance of the specimens. Under the gross methods of observation used, no difference could be noticed between the fishes of the two tests, except in the single blueback. This specimen raised to the surface much more rapidly and deteriorated more quickly. Perhaps the external injury was even more extensive internally and caused a more rapid decomposition.

SUMMARY

A total of 21 salmonoid fishes were killed and placed under observation to determine the length of time it took them to float, how long they remained at the surface, and their external physical appearance at various intervals.

	Chinook	Steelhead	Blueback
Number of specimens	15	5	1
Number raising completely to the surface	14	5	1
Average time required to float to the surface	75 hrs. (3 days)	91 1/2 hrs. (3 da. 19 1/2 hr.)	48 hrs. (2 days)
Average time remaining at surface	152 hrs. (6 da. 8 hrs.)	161 1/4 hrs. (6 da. 17 1/4 hr.)	240 1/2 hrs (10 days)
Variations in time remaining at the surface	2-11 days	6-8 days	

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It should be pointed out that the observed times required for the specimens to float and to remain afloat is probably greater than the actual time in both cases. The specimens could have floated up or sank any time between the time they were first seen or disappeared and the previous observation. A difference of as great as 24 hours is possible.

Observations upon the physical condition of the specimens as they floated to the surface would seem to indicate that it would be difficult for scavengers to destroy the fish sufficiently to prevent its raising to the surface, provided it was not held under water by some physical obstruction. It is possible that fish with cuts or skin abrasions would be more easily attacked and eaten. The fish used in these tests developed a heavy growth of fungus, a condition not noticed in the natural river mortality to any extent. Perhaps the abundant fungus growth was due to the fish being held in more or less quiet water away from the influence of wind and current. It should be realized that the behavior of the fish under observation would not necessarily be that of fish floating free in the water.

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